

**DOE/NETL Project Review Meeting  
Westin Winchester Hotel - Winchester, CO  
September 29-30, 2003**

**In-Situ Sampling and Characterization of  
Naturally-Occurring Marine Methane  
Hydrate: ODP Leg 204, Hydrate Ridge**

**Dr. Frank R. Rack, Joint Oceanographic Institutions  
1755 Massachusetts Ave., NW; Suite 700;  
Washington, D.C. 20036-2102  
Tel: (202) 939-1624; Fax: (202) 462-8754  
Email: [frack@joiscience.org](mailto:frack@joiscience.org)  
<http://www.joiscience.org>**



**Joint Oceanographic Institutions, Inc. / Ocean Drilling Program**



# **D/V JOIDES *Resolution***



**The JOIDES *Resolution* is a uniquely outfitted dynamically-positioned drill ship, that has a seven-story laboratory complex onboard. This vessel has been contracted for the Ocean Drilling Program (ODP) since 1985 to conduct worldwide scientific coring operations.**



**Joint Oceanographic Institutions, Inc. / Ocean Drilling Program**



# **JOI/ODP Proposal to U.S. DOE/NETL “Methane Hydrates” Solicitation**



**NETL awarded \$ 1,438,202 (including cost-share) in Phase 1 of this cooperative agreement, entitled: “In-Situ Sampling and Characterization of Naturally Occurring Marine Methane Hydrate Using the D/V JOIDES Resolution”.**

**Tasks 1-7:** Upgrade the ODP Pressure Core Sampler (PCS), PCS gas manifold, and ODP memory tools (DVTP, DVTP-P, APC-methane, APC-T tools) for use on Legs 201 and 204.

**Acquire equipment to characterize methane hydrates (e.g., G/GI Seismic Gun, Infrared Thermal Imaging System); modify the FUGRO piezoprobe tool for use with the ODP bottom hole assembly (BHA). Geriatrics Study on Leg 204.**



**Joint Oceanographic Institutions, Inc. / Ocean Drilling Program**



# **JOI Cooperative Agreement with DOE/National Energy Technology Lab**



**Deliverable: Task 1.1 - Preliminary Evaluation of Existing  
Pressure/Temperature Coring Systems (October 2002).**

**Report available online at DOE/NETL website.**

**<http://NETL.CERTREC.COM>**

**Login: NETL**

**Password: ARCHIVE**

**Go to Bottom of List (52.4 MB file)**

**HYD\_00037\_2001.PDF**

**739 page summary of information available about four existing pressure  
coring systems synthesized from Technical Notes, JOIDES meeting  
minutes, Web Pages, and other information sources.**



**Joint Oceanographic Institutions, Inc. / Ocean Drilling Program**



# Pressure Coring of Methane Hydrates

**ODP Pressure Core Sampler (PCS):** wireline-retrievable, top-drive rotary/push; standard tool; 10,000 psi (690 bar) max. pressure. Gas manifold system mates to tool for measuring gas volume and composition of gas.

**FUGRO Pressure Corer (FPC):** wireline-retrievable, percussion/push; prototype tool; 3625 psi (250 bar) max. pressure.

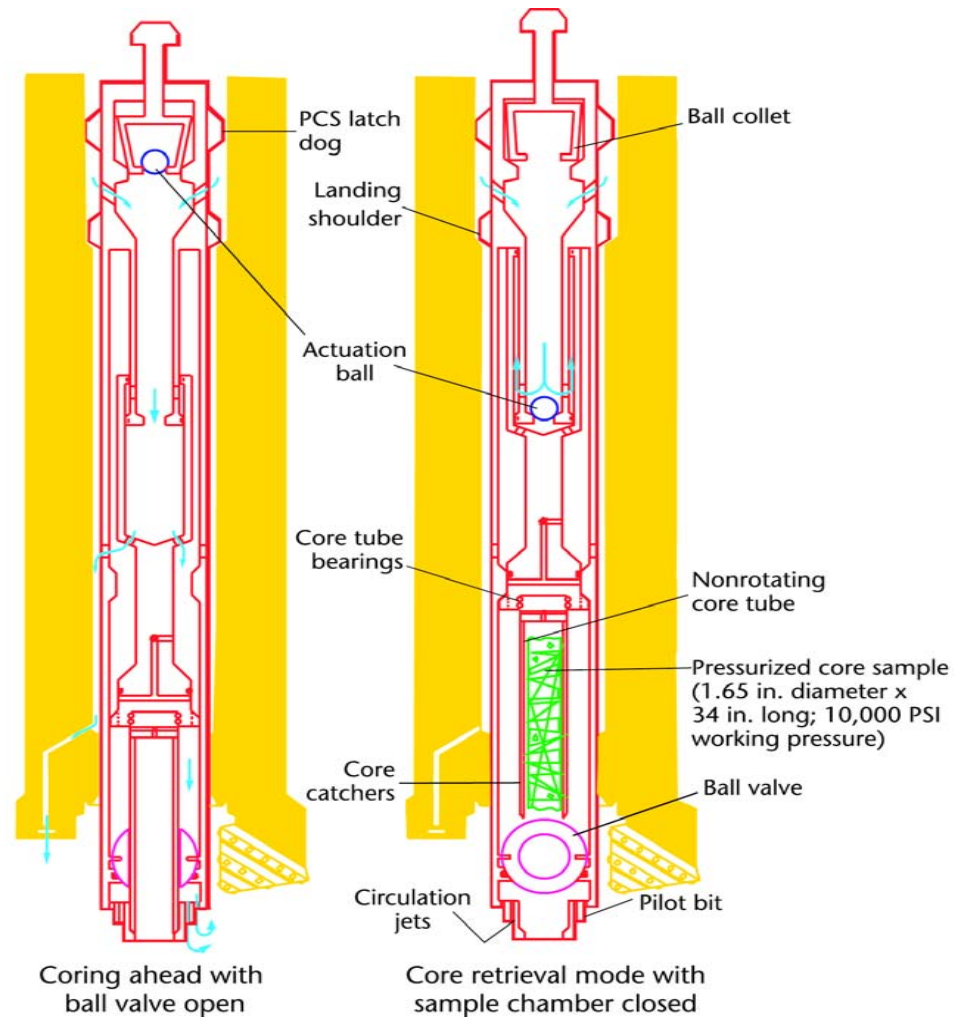
**HYACE Rotary Corer (HRC):** wireline-retrievable, downhole mud motor rotary/push; prototype tool; 3625 psi (250 bar) max. pressure.

**JNOC Pressure Temperature Core Sampler (PTCS):** wireline-retrievable, top-drive rotary/push; 3,500 psi (241 bar) max. pressure.

**Only the ODP PCS Tool testing was part of the DOE/NETL cooperative agreement with JOI. However, JOI negotiated a collaborative agreement with the HYACINTH consortium for testing and use of their two pressure coring tools during ODP Legs 201 and 204 at no cost to the DOE project.**



# ODP Pressure Coring System (PCS) - Task 2



# **ODP Leg 164 (Nov-Dec 1995)**

## **Blake Ridge and Carolina Rise**

### **Operating Parameters for PCS Rotary Coring:**

- **RPM: 40 – 60 rpm**
- **Flow Rate: 200 gpm**
- **WOB: 15 – 20 klbs**
- **Core Barrel Spaced-out where the cutting shoe was positioned at either 0.15 m or 0.46 m ahead of the bit.**

### **ODP Leg 164 PCS Results:**

- **Total deployments: 46**
- **Successful (i.e., core under pressure): 24**
- **Average core recovery: 31%**
- **Average pressure retention: 77%**
- **Average push core recovery 48%**
- **Average rotary core recovery 14%**



# PCS Tool Modifications Prior to ODP Leg 201

- **New Cutting Shoe Designs**
- **Extended Cutting Shoe - Meter Ahead of Bit**
- **Improved Flow to Cutting Shoe**
- **Increased Inner Barrel ID (inside clearance ratio from 5% to 8%)**
- **Eliminated Core Catchers**





# **PCS Cutting Shoe Test at Maurer Facility**

## **November-December 2002**

- **Test Rock: Texas Cream limestone, compressive strength of 2600 psi.**
- **Test Matrix using Flow Rate, Rotation Speed and Weight on Bit as variables.**
- **Conclusions:**
  - **RPM > 150 rpm**
  - **Flow > 200 gpm**
  - **WOB = 3 - 5 klbs**



## ODP PCS Tool Specifications

|               | Leg 164         | Leg 201/204     |
|---------------|-----------------|-----------------|
| Core Diameter | 1.65 in/42 mm   | 1.70 in/43.2 mm |
| Core Length   | 34 in/0.86 m    | 39.4in/ 1.00 m  |
| Core Volume   | 1190 cc         | 1465 cc         |
| Cutter O.D.   | 3.75 in/95.3 mm | 3.75 in/95.3 mm |



Joint Oceanographic Institutions, Inc. / Ocean Drilling Program



# **ODP Leg 201 (Feb-Mar 2002)**

## **Offshore Peru Continental Margin**

### **Operating Parameters for PCS Rotary Coring:**

- **RPM: 100 – 120 rpm**
- **Flow Rate: 100 – 200 gpm**
- **WOB: 7 klbs**

### **ODP Leg 201 PCS Results:**

- **Total Deployments: 17**
- **Successful (core under pressure): 13**
- **Average Core Recovery: 76%**
- **Average Pressure Retention: 67%**
- **Methane Found in Gas Samples: 11 Runs**
- **Methane Gas Recovered: 16 Liters**



# **PCS Tool Modifications Prior to ODP Leg 204**

- **Installed APC Methane Tool at Top of Core Barrel Assembly for Continuous Temperature and Pressure Recording (required removing accumulator).**
- **Increased Strength of Bit Sub Connection**
- **Changed Core Barrel Material to Stainless Steel**
- **Increased Link Pin Diameter for Strength**



# **ODP Leg 204 (Jul-Sept 2002)**

## **Hydrate Ridge, Offshore Oregon**

### **Operating Parameters for PCS Rotary Coring:**

- **RPM: 80 – 100 rpm at depths greater than 100 mbsf, 50 rpm at shallower depths**
- **Flow Rate: 100 gpm**
- **WOB: 5 klbs**

### **ODP Leg 204 PCS Results:**

- **Total Deployments: 39**
- **Successful (core under pressure): 30**
- **Average Core Recovery: 95%**
- **Average Pressure Retention: 64%**
- **Methane Found in Gas Samples: 30 Runs**
- **Methane Gas Recovered: 183 Liters**



# **Factors for PCS Tool Success on ODP Legs 201 and 204**

- **Active Heave Compensator Allowed Weight on Bit Control  
+/-2000 lbs**
- **High RPM (Nominal 100 rpm)**
- **Low WOB (Nominal 5 - 7 klbs)**
- **Cutter Extended 1/2m Ahead of Bit**
- **Increased I.D. of Core Barrel**
- **Cutting Shoe Design**
- **Additional Funding Available for Technology Development  
and Engineering Testing (DOE/NETL Award)**



# Pressure Coring System (PCS) Gas Manifold System (Task 2 cont.)

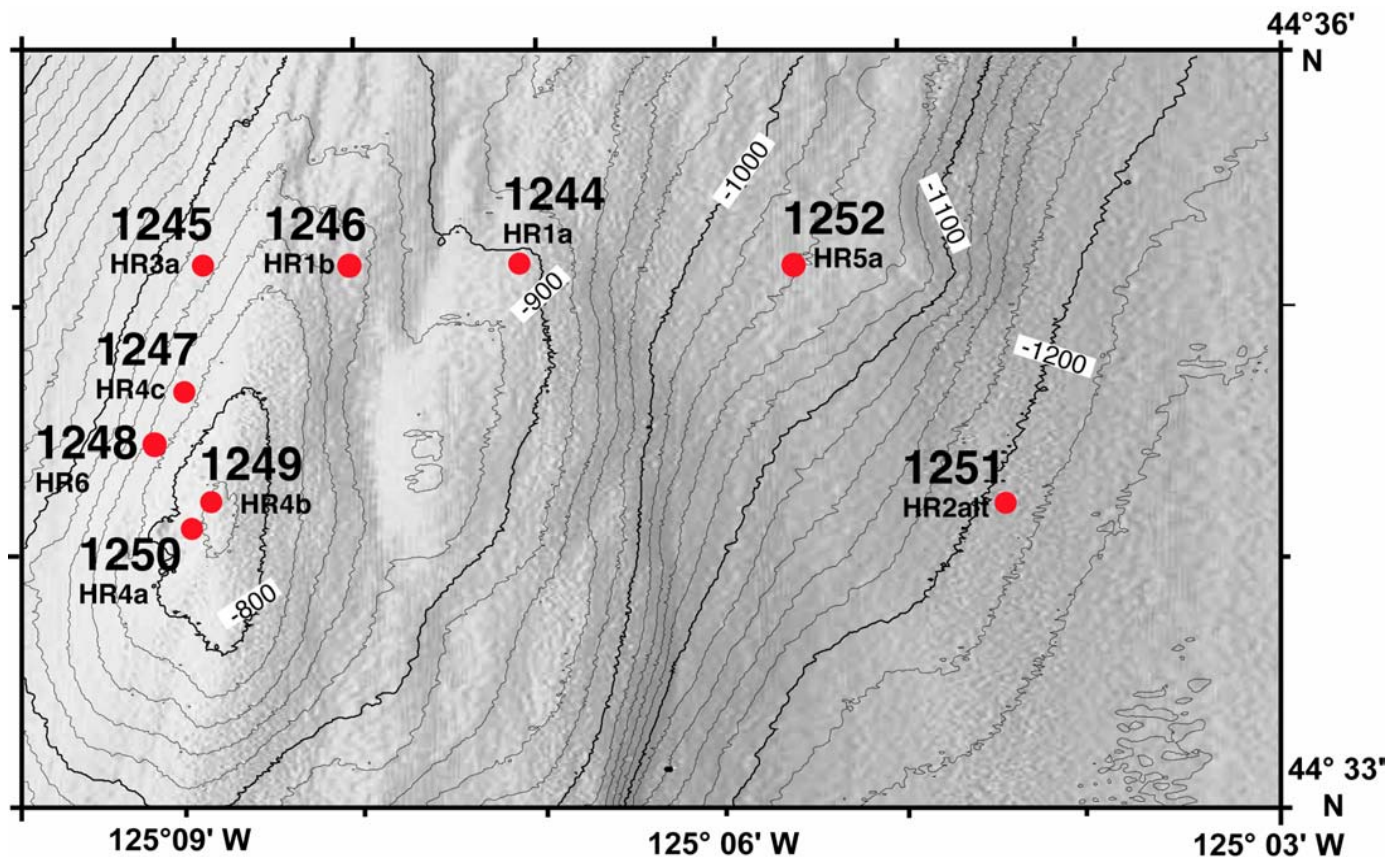


Joint Oceanographic Institutions, Inc. / Ocean Drilling Program





# ODP Leg 204 Site Locations



Joint Oceanographic Institutions, Inc. / Ocean Drilling Program





# Summary of ODP Leg 204 - Hydrate Ridge

- **Leg 204 began and ended in Victoria, B.C., Canada.** The leg was planned as a 59.4 day leg - actually was **57.1 days** long.
- **50.4 days** (88.3%) was spent **operating**; 6.7 days (11.7%) were spent in port and/or in transit to/from Hydrate Ridge.
- Overall, **9 Sites** were drilled/cored, with a total of **45 Holes**.
- **Water depths** of sites ranged from **788.5 mbrf** to **1228.0 mbrf**.
- **Penetration depths** varied from **9.5 mbsf** to **540.3 mbsf**.
- 8 of 9 sites were drilled using **LWD** (resistivity-at-bit, NMR, density/neutron) technology.
- Eleven (11) holes were drilled using a tricone bit for LWD or wireline logging. Thirty-three (33) holes were cored using APC and/or XCB coring systems; 1 hole was cored with RCB.



# Summary of ODP Leg 204 Coring Activities

- Over 3674.5 meters of sediment were cored and 3068.3 meters of sediment was recovered (83.5% core recovery).
- Nine rendezvous with the D/V *JOIDES Resolution* took place during Leg 204; including 7 helicopters and 2 supply boats.
- 42 personnel were exchanged on/off the ship.
- A series of holes were dedicated to the rapid recovery and preservation of hydrate-bearing sediment cores for a “Geriatric Study” of hydrates [DOE/NETL Task 7] which was cooperatively-funded by DOE-NETL and NSF/ODP.
- 50 meters of hydrate-bearing core was recovered and stored in steel pressure vessels at 4°C and 600 psi using methane gas. Steel pressure vessels are 3” I.D. and are rated to 3000 psi; Core is 2.66” O.D. (goal was to minimize head space of gas).
- 35 meters of hydrate-bearing core was recovered and stored in 8 liquid nitrogen cryo-freezers (160 liter capacity each) at the ODP Gulf Coast Repository.



# Summary of Pressure Coring Activities on Leg 204

- 30 out of 39 runs with the **ODP Pressure Core Sampler (PCS)** were successful (core under pressure recovered). One PCS core contained 95 liters of methane from a ~1 meter-long core [**DOE/NETL Task 2**].
- 2 out of 10 runs with the (HYACINTH) **Fugro Pressure Corer (FPC)** were successful.
- 4 out of 8 runs with the (HYACINTH) **HYACE Rotary Corer (HRC)** were successful. One HRC core contained 105 liters of methane from a ~1 meter-long core.
- Cores were recovered with the **ODP Advanced Piston Corer**, transferred to the **ODP-Logging Chamber (ODP-LC)**, repressurized and logged.
- Cores were recovered with the HYACINTH FPC and HRC under pressure, were transferred under pressure to a logging chamber, and were logged using the **GEOTEK vertical-multi-sensor core logger (V-MSCL)**.



# Summary of Leg 204 Specialty Tool Deployments

- 81 out of 81 successful runs with the **APC-Temperature Tool** (memory tool that fits into APC coring shoe) [**DOE/NETL Task 3**].
- 8 out of 8 successful runs with the **Davis-Villinger Temperature Probe (DVTP)** [**DOE/NETL Task 3**].
- 16 out of 16 successful runs with the **Davis-Villinger Temperature Probe with Pressure (DVTP-P)** [**DOE/NETL Task 3**].
- 1 out of 2 successful runs with the **Fugro Piezoprobe tool** [**DOE/NETL Task 6**], which measures pore pressure dissipation *in situ*. This tool is run on the Schlumberger logging cable (real-time data) as opposed to the wireline deployment of the DVTP-P (data in memory).
- 107 out of 110 successful runs with the **APC-methane Tool** [**DOE/NETL Task 3**], which includes Temperature, Pressure, and Conductivity sensors in the APC piston head (time series measurements).



# Summary of Leg 204 Specialty Tool Deployments

- Cores were collected during LWD activities at Site 1249 using a **prototype RAB-C system**, which was an integration of the Schlumberger/Anadrill resistivity-at-the-bit (RAB) LWD tool and the ODP motor-driven core barrel (MDCB) core tube [**DOE/NETL Task 5**]. The MDCB core tube fits inside the annulus of the RAB tool.
- 28 runs with the **LDEO DrillString Acceleration (DSA) tool**; 17+ runs were fully/partially successful. Low temperatures affected tool performance on this leg.
- **Vertical seismic profiling (VSP) experiments** were conducted at several sites using a range of techniques (e.g., VSP, offset-VSP, walkaway VSP) [**DOE/NETL Task 5**]
- Impact of the APC into hard hydrate layers at Site 1249 was used as an **energy source** to record acoustic data using ocean bottom seismometers deployed nearby.
- **Physical** (whirlpak bags filled with 10 micron-sized fluorescent beads) **and chemical** (perfluorocarbon - PFT) **tracers** were used on 88 cores to provide QA/QC for microbiological sampling and contamination studies.



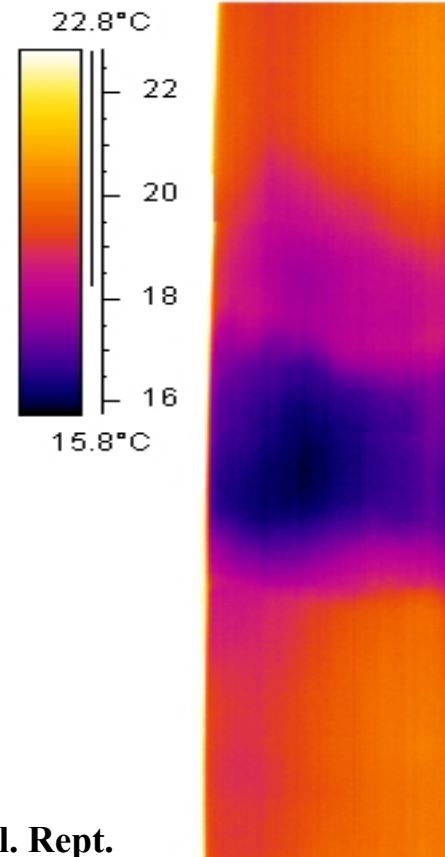
# Summary of Leg 204 Core Measurements

- Rigfloor handling of core barrels was optimized to reduce time between recovery of cores and delivery to the catwalk. **Hydrate safety handling protocols** were used from rigfloor to catwalk. **Hydrogen Sulfide safety protocols** were used routinely.
- Core liners were immediately scanned on the catwalk using one or more **FLIR ThermoCam SC2000 infrared thermal imaging systems** (automated track-mounted, and hand-held IR cameras) to observe thermal (cold) anomalies, which correlate with gas hydrates in the core [**DOE/NETL Task 4**].
- **Gas hydrate samples** found in cores were immediately **stored in liquid nitrogen or in pressure vessels** [**DOE/NETL Task 7**], or were dissociated and analyzed by injection into gas chromatographs (GC's) onboard. GC's were used for **routine hydrocarbon monitoring** according to ODP drilling/coring safety procedures.
- **Whole-round core samples** were collected, trimmed, and squeezed in the onboard chemistry laboratory to obtain **interstitial (pore) waters** to measure geochemical properties (e.g., chlorinity) and produce downhole profiles.



# FLIR ThermaCam SC2000 IR-TIS - ODP Leg 201

## First Thermal Image of Hydrate Sample - Site 1230



D'Hondt, Jorgensen, Miller, et al., 2002. ODP Leg 201 Prel. Rept.

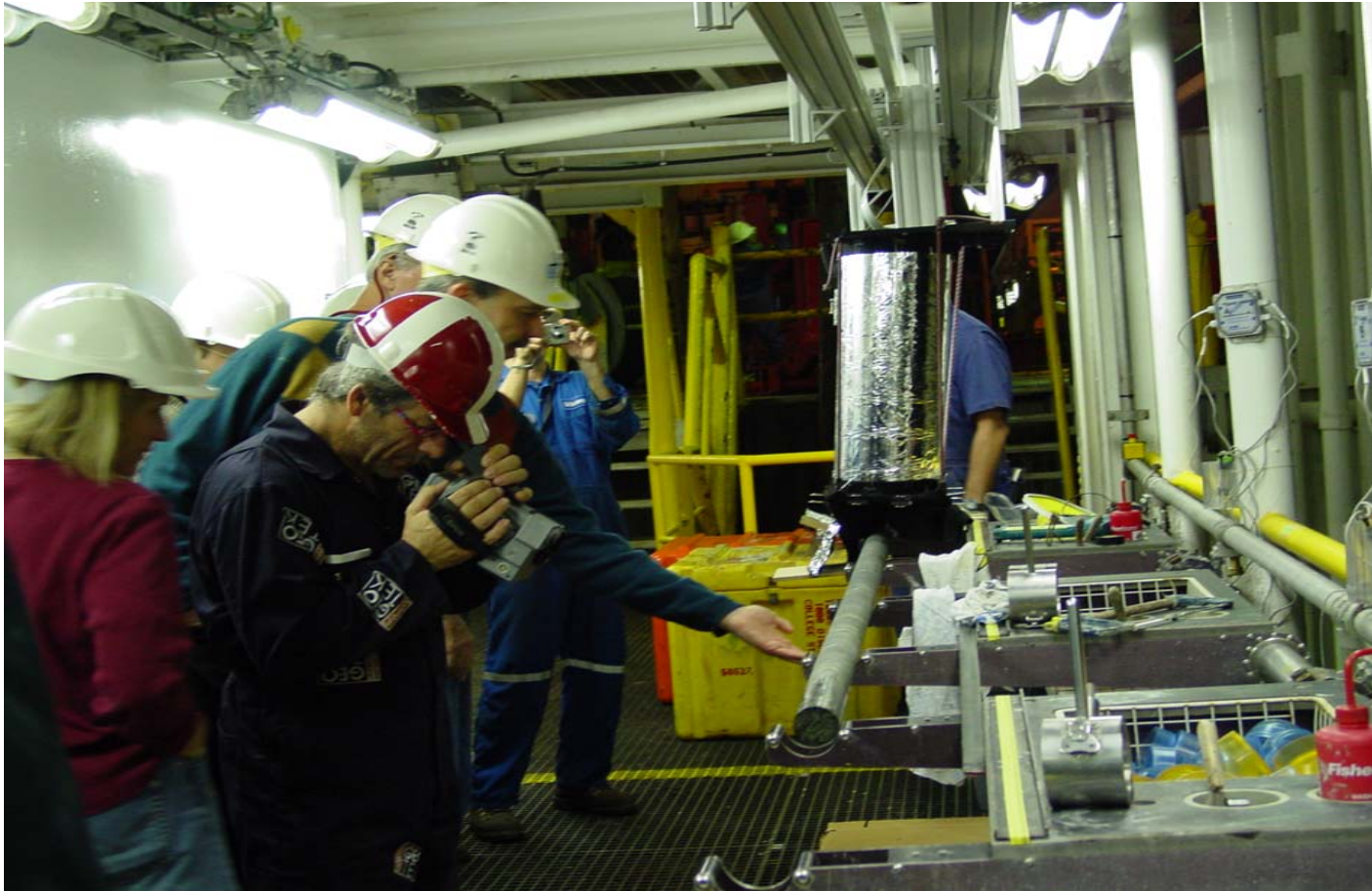


Joint Oceanographic Institutions, Inc. / Ocean Drilling Program





# Automated and Manual Catwalk Infrared Thermal Imaging of Sediment Cores During ODP Leg 204



Joint Oceanographic Institutions, Inc. / Ocean Drilling Program





# Summary of Leg 204 Core Measurements

- Most cores were imaged using a whole-core **X-ray linear scanner** developed by Lawrence Berkeley National Laboratory by Barry Freifeld and others with funding from DOE/NETL [**JOI cooperative project with DOE/NETL and LBNL**].
- All cores were passed through the ODP **multi-sensor core logging system**, which provides closely-spaced measurements of gamma density, inductive conductivity (resistivity), magnetic susceptibility, compressional (P-wave) velocity.
- **All cores were visually described** by shipboard sedimentologists to identify sedimentary structures, fabrics, composition, grain size, etc.
- **All cores were visually imaged** using a digital line-scan imaging system **and photographed** using color and black & white film.
- At each site, **age control** was provided by diatom and nannofossil biostratigraphy.
- Extensive **physical properties measurements**, and **geochemical and microbiological sampling** was conducted on all cores recovered.



# JOI/ODP Cooperative Geriatrics Study with DOE/NETL

Dr. Frank Rack proposed a **geriatric (long-term) sample preservation** effort to DOE/NETL while onboard the *JOIDES Resolution* during ODP Leg 204.

Funding was received to coordinate sample recovery and preservation using (a) **Steel Pressure Vessels** and (b) **Liquid Nitrogen Cryofreezers**. Samples were returned from Victoria, B.C., Canada to the ODP Gulf Coast Repository for post-cruise analyses and storage in a HAZMAT Container.

Experiment design, equipment and supplies procurement, planning for logistics and shipping, hazardous transport clearances (USDOT, Canadian DOT), and other activities were accomplished within **5 week time frame, start to finish**.

~50 meters of hydrate-bearing core samples from **ODP Site 1249** were preserved using methane as the carrier gas in pressure vessels at 600 psi; ~35 meters of hydrate-bearing core samples were preserved in liquid nitrogen and stored in cryofreezers at the ODP Gulf Coast Repository.



# Pressure Vessels and Cryofreezers in Refrigerated Van Used for “Geriatrics Study” Initiated on ODP Leg 204



Joint Oceanographic Institutions, Inc. / Ocean Drilling Program



# What was the Estimated Cost of ODP Leg 204?

|                          |   |                                      |
|--------------------------|---|--------------------------------------|
| <b>NSF/ODP</b>           | <b>\$5.3 Million U.S. Dollars</b>               | <b>Shipboard Operations</b>          |
| <b>DOE/NETL</b>          | <b>\$1.5 Million U.S. Dollars*</b>              | <b>JOI Cooperative Agreement</b>     |
| <b>NSF (Ewing)</b>       | <b><i>\$0.5 Million U.S. Dollars (est.)</i></b> | <b>Offset/Walkaway VSPs</b>          |
| <b>EC-HYACINTH</b>       | <b><i>\$1.0 Million U.S. Dollars (est.)</i></b> | <b>Pressure Coring Tests</b>         |
| <b>Subtotal</b>          | <b>\$8.3 Million U.S. Dollars</b>               | <b>Direct Operational Costs</b>      |
| <b>NSF/JOI-USSSP</b>     | <b>\$0.8 Million U.S. Dollars</b>               | <b>U.S. Science Support</b>          |
| <b>USGS/DOE</b>          | <b><i>\$1.0 Million U.S. Dollars (est.)</i></b> | <b>Interagency Science Support</b>   |
| <b>International</b>     | <b><i>\$1.0 Million U.S. Dollars (est.)</i></b> | <b>International Science Support</b> |
| <b>Subtotal</b>          | <b>\$2.8 Million U.S. Dollars</b>               | <b>Science Support Costs</b>         |
| <b>Total Cost (est.)</b> | <b>\$11.1 Million U.S. Dollars</b>              | <b>Shipboard &amp; Postcruise</b>    |

**\* Including cost sharing as part of JOI cooperative agreement with DOE/NETL**



**Joint Oceanographic Institutions, Inc. / Ocean Drilling Program**

